REVIEW OF LAKE STURGEON ANALYSES FOR THE PROPOSED KEEYASK GENERATING STATION

Context

Keeyask is a generating station being proposed for the Nelson River in Manitoba. As part of a Comprehensive Study Level environmental assessment, Fisheries and Oceans Canada (DFO) must make a determination on whether there are likely to be significant adverse environmental effects, after considering mitigation, from construction and operation of the proposed Keeyask generating station. A key element in the determination is whether Lake Sturgeon in the Nelson River will be adequately conserved.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed Nelson River populations of Lake Sturgeon (Designatable Unit [DU] 3) as Endangered in November 2006 (COSEWIC 2006) and it is now being considered for listing under the *Species at Risk Act* (SARA). The area where Keeyask would be built is considered important to Lake Sturgeon recovery in the Nelson River.

The Proponent for the Keeyask generating station has proposed new population viability analyses[1] since the Recovery Potential Assessment (RPA) was published. Fisheries Protection Program has requested DFO Science review the proposed analysis and evaluate whether Lake Sturgeon, potentially impacted by construction and operation of the station, would likely be adequately conserved so that their recovery would not be further threatened by Keeyask.

A response from Science is required by January 9, 2014 to meet the January 16th 2014 deadline for the Departmental response to the Canadian Environmental Assessment Agency. This Science Response Report results from the Science Response Process of January 2014 to review the Lake Sturgeon analyses for the Keeyask Generating Station.

Background

DFO Science provided advice to the Department through a recovery potential assessment (RPA) for Lake Sturgeon in this DU in October 2009 (DFO 2010). The Nelson River has been affected by significant hydroelectric development, including diversion (Churchill River diversion), water management (Lake Winnipeg regulation), and five generating stations other than Keeyask. The construction of hydroelectric dams, beginning in 1960, fragmented the distribution of Lake Sturgeon and isolated the species into a series of reservoirs, particularly between Kettle and Limestone generating stations (Figure 1). The Keeyask generating station is planned for the segment of the Nelson River between Kelsey and Kettle generating stations, referred to as Management Unit (MU) 3.

Dams and control structures elsewhere have been shown to alter the natural flow regime and fragment habitat resulting in degradation and/or loss of Lake Sturgeon habitat, loss of genetic diversity, reduced spawning success, reduced prey availability and mortality (Cleator et al. 2010). Dam construction can extirpate local Lake Sturgeon populations (Cleator et al. 2010) by

[1] Manitoba Hydro response to DFO Information Request dated 19 December 2013 archived by the Canadian Environmental Assessment Agency, including attachment 1 (Response to supplemental questions TAC Public Rd 3) and attachment 2 (Lake Sturgeon population viability analysis and risk assessment for the Keeyask Generating Station Project).

preventing fish from accessing spawning areas and stranding fish between impassable barriers. Larger structures, like hydroelectric dams, can also cause direct mortality, injury or reduced survival by entrainment, impingement and fish passing downstream through the turbines.

The most important current threats to survival and recovery of Lake Sturgeon in DU3 are habitat degradation or loss resulting from the presence of dams/impoundments and other barriers, mortality, injury or reduced survival resulting from fishing, and population fragmentation resulting from the presence of dams/impoundments and other barriers (DFO 2010). Survival and recovery of Lake Sturgeon in DU3 depend on maintaining the functional attributes of habitat, including the ecologically-based flow regimes needed for spawning, egg incubation, juvenile rearing, summer feeding and overwintering, as well as migration routes between these habitats. The current status of Lake Sturgeon in MU3 is thought to be cautious although the trajectory of the population is unknown (DFO 2010).

Keeyask Hydropower Limited Partnership (KHLP) used DFO's recently developed Lake Sturgeon population risk assessment model (based on a demographic approach developed by Vélez-Espino and Koops 2009a, 2009b) to address concerns with respect to uncertainties in population outcomes. KHLP indicated that their initial output shows that risks to the local Lake Sturgeon population are substantially less with the Keeyask Project in place than under current conditions, primarily as a result of the proposed stocking plan. The length of recovery time and risk of serious declines are reduced by approximately half of those under existing conditions. Their conclusions depend on stocking of Lake Sturgeon.

KHLP acknowledged that without upstream fish passage facilities at Keeyask, the Project will split Lake Sturgeon MU3 into upstream and downstream units and that portions of each will be affected by the Project. They plan to provide sufficient habitat upstream and downstream to support self-sustaining Lake Sturgeon populations, construct spawning habitat and maintain desired velocities during the spawning periods.

Analysis and Response

Lake Sturgeon populations in the Nelson River (DU3) are endangered, historically because of overexploitation, and more recently because of dams and habitat fragmentation. Lake Sturgeon undergo extensive migrations for spawning, and large open distances (250 to 1000 km) are needed to support self-sustaining populations (Auer 1996). Lake Sturgeon are one of the largest freshwater fish species (large body size at maturity), and their habitat requirements are spatially extensive.

Modelling

The life-stage model that was used for the population viability analysis and risk assessment, for both existing and post-project scenarios, was adapted from the DFO model that was developed for recovery potential assessment (Vélez-Espino and Koops 2009a, 2009b). The five stage model is illustrated in Figure 4 of their document. RAMAS software (Akçakaya and Root 2013), often used in the science literature for species at risk population models, was used for the Keeyask project. The Vélez-Espino and Koops model and the RAMAS platform are appropriate and scientifically sound.

Different scenarios were modelled for the existing and post-project comparison and assessment. The various scenarios were based on different dispersal and stocking patterns, as well as other factors and assumptions. The key comparison for the modelling was the Lake Sturgeon population viability for the existing versus post-project periods. The validity of the model output depends entirely on the input parameters and the assumptions. The model was parameterised by the Proponents for the Lake Sturgeon population in the Keeyask area.

Interpretations of the findings in the report are limited. The tables of results are helpful, but would be more so with graphics showing comparisons. The current text on comparisons is vague, saying simply that "scenario A recovered faster than B" without describing how much, or how this compares to other uncertainties. It's obvious that 50 years of stocking is better than 25, but are the returns diminishing? For example, is stocking with low dispersal effectively the same as no stocking with high dispersal or are results more sensitive to dispersal assumptions than to the amount of stocking?

Several times in the document KHLP mentions that the recovery target used for the modelling is conservative, and that it would have been lower if population specific size-at-age data had been used. The report doesn't explicitly state why this is the case. If it is indeed correct, and if this lower MVP is known, the corresponding change in recovery time should be provided. That said, DFO supports the Proponent's use of a more conservative scenario for considering project impacts.

It is unclear if varying the sex ratio from 1:1 would have any effects on the modelling outcomes. The sex ratio might be skewed if the ~8% harvest that occurs was to selectively remove either females or males. Males typically occupy the spawning areas in advance of females arriving and after the females leave so they would potentially suffer higher harvest rates if harvesting occurs on the spawning area and the net mesh sizes used have a uniform selectivity for all size classes of fish. The latter assumption is likely incorrect.

In developing the risk assessment, the existing Lake Sturgeon population in the Nelson River was compared with a healthy population in the Winnipeg River between the Slave Falls and Pointe du Bois Generating Stations. But it is not clear if the comparison is valid. Is the productivity in the Nelson River comparable to that portion of the Winnipeg River?

Density-dependence

It is likely that growth, length-at-age, fecundity, etc. will change over time due to the increasing number of individuals from the enhancement program. RAMAS uses the following approaches to implement density-dependence:

i. no density-dependence (leads to exponential population growth),
ii. a ceiling (essentially exponential population growth until the ceiling is hit),
iii. scramble competition (implements a Ricker style of density-dependence),
iv. contest competition (implements a Beverton-Holt style of density-dependence), or
v. a user-defined function.

KHLP's model implements option (iii) and considers the abundance of all stages when applying density-dependence. This should simulate some of the inter-cohort density-dependence which seems to occur. Implementing density effects on somatic growth would require a user-defined function if there were data to describe the function.

Stage-1 survival

The model will be sensitive to variation in stage 1 survival. Increasing the variation in stage 1 survival would increase the risks of an extirpation in one or more of the sub-populations. The 50% variation in stage 1 survival is reasonable although there was some thought that it should be much more severe (75%) as that seems more realistic in natural populations. The variation in the other survival rates is based on inter-annual variability in survival rates estimated from a mark-recapture study. The 50% variation in stage 1 survival produces inter-annual variability in lambda values that are consistent with estimates from the mark-recapture study. The Proponent did not explain this very well (or at all) in their document. The implicit assumption here is that the

project (e.g., conversion from river to reservoir) when mitigated by habitat creation and stocking will not affect variation in any of the vital rates. It is unclear if vital rate variation will remain unaffected, increase or decrease. There is evidence in the literature that variation increases with increasing mortality. So if we expect mortality to increase post-project, then we should also expect the variation to increase which, in turn, will increase the risks.

Based on the Proponent's description of the current population structure a 25% decrease in larval survival seems too low especially given that recruitment failure appears to be the norm in Lake Sturgeon populations. In our expert opinion, the assumed 25% decrease in recruitment for 9 of every 10 years does not appear to have as large an impact on the age-0 population as would be expected.

Harvest

Harvest rates are only applied to stages 4 and 5 (adults) in the modelling. The rate used is based on the current rate of the Aboriginal harvest. By holding the rate constant, the actual harvest catch increases (or decreases) as the population increases (or decreases).

The identified harvest level of about 8%, is likely not sustainable and may be the reason why the population is depressed. Was there any thought given to modelling a change in harvest? Will harvest increase once stocked fish become available to the fishery? When all the populations of Lake Sturgeon in Canada are considered it is the ones that have had historically significant harvest pressure that are most imperilled. The stocking efforts may establish a put-and-take fishery for Lake Sturgeon that will promote higher harvest rates and subsequently even greater impacts on the natural population. Conducting modelling with different harvest rates would be very useful to look at changes in recovery time.

The Sensitivity Analysis indicates mortality (modeled as harvesting) of the Stage-1 drift but these fish are too small to harvest.

Time to recovery

The times to recovery indicated in the modelling are projected so far into the future that it will be several generations of biologists before the population is expected to fully recover. Is this a reasonable timeframe to manage recovery? It is important that bottlenecks in recruitment and mortality are identified and mitigated wherever possible. Eliminating harvest may result in comparable recovery times, to that projected from stocking, and is controllable, cost effective and would leave the natural population in place.

Downstream movement

The 4.5% movement rate used by KHLP in the model is based on their mark-recapture study using larger individuals. They have no data on downstream movement of age-0 sturgeon. Earlier modelling runs used higher downstream movement rates but the upstream populations didn't fare well. Assuming low downstream movement rates for age-0 sturgeon is of concern. The science literature indicates that the observed distance of larval drift of Lake Sturgeon in large rivers can be significant (measured in kilometres). The Proponents assurance that there is limited age-0 movement doesn't match what we know about the ecology of this species. Larval Sturgeon will move tens to hundreds of kilometers downstream in large river systems although once the larval drift period ends, age-0 sturgeon move very little. The distances in the reach upstream of Keeyask to Birthday Rapids are within the observed range of larval drift for the species (Auer and Baker 2002). The area identified as the principle habitat with the highest density of larval fish is less than 8 km from Keeyask. The creation of the reservoir will likely modify the larval drift in this reach and passage may still be an issue. In addition, it is not clear why there was a range in reported upstream and downstream movements, what the data source

was for this and why these data differ from the acoustically tagged fish. Larval drift rates and distances may be more extensive than suggested by the Proponents.

Genetics

Genetic evidence was used by KHLP to infer movement rates or distances. They stated that genetic studies (Côté et al. 2011) have demonstrated that populations in different parts of the Nelson River are distinct, indicating that large-scale downstream drift of larval fish is not occurring. The F_{st} values reported are extremely low for comparisons within the Nelson River and between the Nelson and Hayes rivers. Although these comparisons may be statistically significant this does not necessarily imply they have ecological significance. Based on Welsh et al. (2008) F_{st} scores in the range of <0.05 indicate low genetic differentiation (i.e., divergence). Therefore all of the within-Nelson River comparisons show low divergence. The Hayes River is also low and the Churchill is moderate. This indicates little differentiation within the Nelson River and suggests movement has occurred historically. Further analyses (allele frequencies, pairwise comparisons) could develop a better understanding of divergence in the populations. Bayesian analyses (STRUCTURE software) could be used to determine the number of groups. There needs to be a better understanding of grouping and divergence. Welsh et al. (2008) develops some of these analyses and Welsh et al. (2010) and Schueller and Hayes (2011) give guidance on genetics and stocking.

If stocking is planned and goes ahead then more genetics work needs to be done to develop a plan. Choice of parents for stocking needs to be limited to these same population units which means acquiring brood stock could be more difficult. It is not clear whether the genetic analysis was used as the basis for the argument that passage is not needed at the existing or new facilities within the population units identified. It is also not clear whether the genetic results support low downstream movement. This raises the question about the importance of upstream movement. The model is parameterized with only downstream movement post-project.

Impingement

Discussion of impingement of large sturgeon needs to incorporate more of the precautionary principle. In other words, even if the data are uncertain or haven't yet been published we should err on the side of caution. It is difficult to believe that, given the flows involved, if large Lake Sturgeon encounter the trash racks they will not become impinged. It is possible that the reservoir and noise from the facility will limit encounters, but a more cautious tone is warranted.

Approach velocities are usually in the range of 0.97-1.7 m/s at existing Nelson River Stations. Impingement probability is higher than 0 but less than 50%. Pallid Sturgeon and Shortnose Sturgeon can withstand velocities of 0.6 m/s (Kynard and Horgan 2001).

It is not clear why KHLP has not considered installing screens on its facilities. In a number of jurisdictions this is standard practice (although so is fish passage). The impingement risk is higher on the screens but the number of fish lost to passage and high mortality rates experienced with passage are avoided. KHLP makes a number of points regarding the issue with increasing the bar rack spacing. This would increase impingement at the facility. It is not clear whether "culminating in velocities of approximately 1.2 m at the trash racks" is in reference to decreasing the bar spacing or what the modelled velocities are expected to be. If KHLP had designed a larger intake appropriate for closer bar spacing or even screens then the impingement risk would remain low, passage would be lower and subsequent direct mortality would be lower.

Modelling fish stocking scenarios

Post-project model results are based on various fish stocking scenarios. An implicit assumption in the model is that stocked fish experience the same survival, growth and maturity as wild fish and behave in the same way. The scientific literature, although often based on other species (e.g., salmonids), does not support this assumption. Stocked fish often perform poorly when introduced into a new environment compared to fish which have adapted to the area. If stocked fish actually experience lower survival, then this is equivalent in the model to stocking fewer fish. The effective number of fish stocked is the actual number stocked minus the number lost due to lower survival. The model could be used determine how effective stocking needs to be in order for the project to have a null effect on population growth (i.e., how much stocking is required to balance the effects of the project). What this approach would not do is consider any adverse effects of higher stocking numbers on wild fish through density-dependent effects.

There was no discussion of uncertainty around the effectiveness of stocking. Is there a risk of higher mortality among stocked individuals? Is the proposed stocking feasible? The model results are so dependent upon stocking that whether or not it can be expected to work should have been discussed. The source of the stocking rates should also be explicit.

The anticipated increase in Lake Sturgeon populations post-project is due to a significant enhancement effort. The success and effectiveness of fish stock enhancement have long been questioned and discussed; to the best of DFO Science's knowledge the evidence for positive genetic or ecological effects on existing fish stocks resulting from enhancement programs is limited while there are a number of studies indicating neutral or negative effects. This is a critical problem with KHLP's plan. The low natural recruitment and adult abundance will only be exacerbated by the construction of a new facility, and the stocked fish will quickly dominate the population. The genetics of the remnant population will be impacted, and there are uncertain ecological outcomes (differences in movement, spawning site fidelity, etc.) too. DFO Science is concerned that the risks and benefits of stocking may not be fully evaluated.

If stocking is considered it should follow the approach taken by Holtgren et al. (2007). "The streamside rearing facility facilitates rearing of wild-caught lake sturgeon larvae in their natal water. This rearing approach provides a cost-effective technique for small batch rearing, incorporates aspects of genetic conservation, and addresses concerns about imprinting and spawning site fidelity." Mann and Holtgren (2011) provides support for this approach.

Implications of stocking have to be considered within the context of the genetic integrity of Lake Sturgeon populations within DU3 with respect to the *Species at Risk Act* and COSEWIC's interpretation of native wildlife species and designatable units. It is important to ensure broodstock, fertilized eggs and/or larval fish are from the same genetic stock.

Offsetting habitat losses

Plans to offset habitat losses (creating spawning habitat) are untested. The model assumes only a slight reduction in production when the habitat becomes fully functional. This is likely overly optimistic. The creation of habitat does not mean that it will be utilized, and it is the productivity of available habitats that are important. Under ideal conditions it is likely that only a small spawning area is necessary, but our understanding of Lake Sturgeon spawning requirements is incomplete. Therefore at a minimum a 2:1 ratio should be used for the estimated habitat creation requirement. It is not clear whether KHLP has undertaken a thorough review of potential enhancement risks. If not, then they should.

Conclusions

The model used is appropriate. If the assumptions about Lake Sturgeon biology and stocking used in the model are correct or approximately correct, then DFO would have as much confidence in its results as we have in any of the models we build and use. However, DFO Science has concerns with various population parameters that were chosen for the Keeyask model. Specifically, if any of the following is true, then the recovery of Lake Sturgeon could be at greater risk than this report suggests:

- greater downstream movement of age-0 than currently modelled, especially since there will be no upstream movement possible post-project;
- post-project changes to vital rates or the variability in vital rates, specifically reduced survival or growth or increased variance or increased chances/occurrence of recruitment failure;
- if stocking is less effective than expected or there are unanticipated adverse effects from stocking given that all post-project scenarios involve stocking.

The genetic evidence to infer movement rates is also of concern to DFO Science. Caution should be used to infer low movement rates without a more in-depth review of the literature.

Post-project model results with increased Lake Sturgeon abundances are dependent on a significant enhancement effort through a stocking program. The model parameters appear to be based on the assumption that the stocked fish will behave and survive in a manner similar to native sturgeon. The scientific literature, although often based on other species (e.g., salmonids), does not support this assumption. Stocked fish often perform poorly when introduced into a new environment compared to fish which have adapted to the area. DFO Science is concerned about the reliance on stocking to mitigate Project impacts.

Plans to offset habitat losses (creating spawning habitat) are untested. The model assumes only a slight reduction in production when the habitat becomes fully functional. This is likely overly optimistic.

For these reasons, the model output results for the post-project scenarios are uncertain and likely too optimistic.

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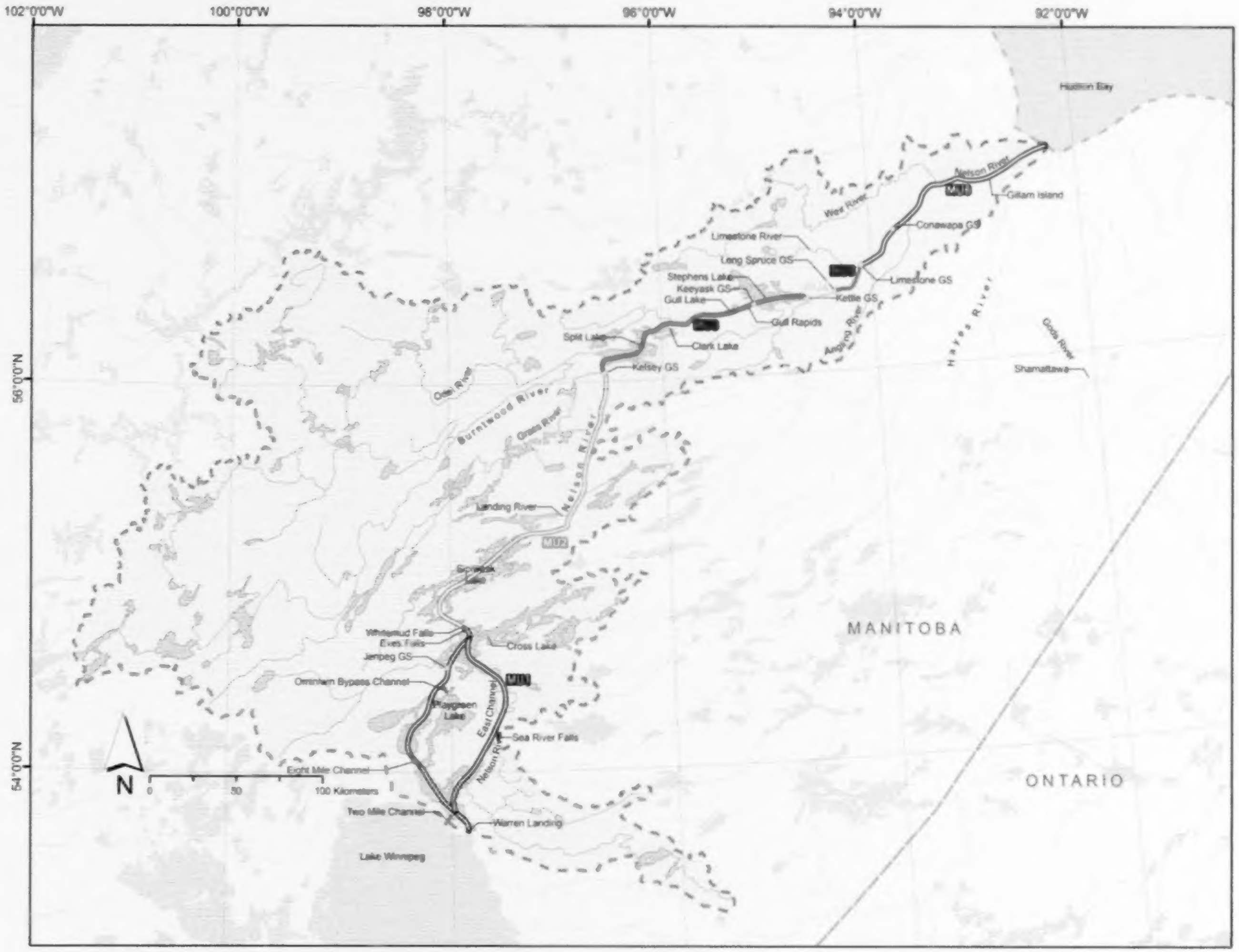

Figure 1. DU3 showing locations of Management Units (MU) and generating stations on the Nelson River (from DFO 2010) including the Keeyask generating station within MU3.

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